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The role of buildings in the energy transition in the context of the climate change challenge

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ABSTRACT

In order to redefine the influence of the energy and technological transitions upon the challenge of climate change this paper shows that buildings are key agents. This paper discusses the importance of addressing building energy efficiency in a holistic and transformational way, to avoid that incremental measures increase the lock-in effect. Moreover, policies should consider a demand-side energy transition, contrary to today's discourse, where the supply side and energy production are prominent. Finally, the most important issues in this energy transition are intergenerational divide and justice.

The climate change challenge redefines many aspects of the energy and technological transitions. There is a need to reconsider many of the concepts used today by policy-makers and individuals if we want to change the pathways followed until today. This paper shows that buildings can be among the most optimal agents to reach climate goals, considering social, environmental, ethical and economic aspects. However, if measures to promote building energy efficiency are not approached from a systemic transition perspective, but in an incremental, piecemeal way, such an approach may actually do more harm to reaching climate goals than advances. Measures encouraging or accepting renovation or changes that do not achieve all potential energy efficiency means locking again the potential for the remaining reductions, since these become very expensive. This also has social consequences (i.e. energy poverty, health goals), therefore, it is better to fully retrofit a few buildings than to half retrofit a lot of buildings [1].

The Intergovernmental Panel on Climate Change (IPCC) Special Report Global Warming of 1.5 °C [2] highlights new constraints in the energy transition and new agenda in the context of the most stringent goals of the Paris Agreement. This report presents four illustrative pathways that meet the "well under two degrees" target of the Paris Agreement [3], representing four different visions of the future under which the 1.5 °C warming cap is met. Fig. 1 presents these in a breakdown of contributions to global net CO_2 emissions by key mitigation approach (Fig. 1).

The majority of these pathways, but specially P4, rely heavily on negative emissions, but the success of this concept has already been questioned, since lock-in of technologies and neglecting embodied carbon can be a consequence raised by it [4]. In all pathways bioenergy with carbon capture and storage (BECCS) is considered as a technology to decrease CO_2. But BECCS raises different concerns [4,5]. The first one is the competition for land with food production and other land demands such as urbanization; competition for biomass resources for construction materials, fuel, etc.; implications in water resources; indirect carbon emissions from life cycle emissions associated to the supply chain (e.g. 70% of biomass for UK Drax Power was imported from USA at 36 gCO_2/MJ) [5]; embodied energy in biomass due to processing (pelletization) and transport [6]; timing, since the "carbon debt" initiated by land conversion to biomass production cannot offset CO_2 savings from displacing coal, or only over a period of time that is greater than the power plant lifetime; biodiversity implications; and chemical input requirements. This brings an ethical concern, since pursuing scenario P4, heavy on BECCS would leave a huge heritage to future generations.

The only pathway that avoids the planetary scale deployment of controversial negative emission technologies is P1. This pathway demonstrates that it is still possible to achieve carbon neutrality by 2050 even without large-scale reliance on these contested emission

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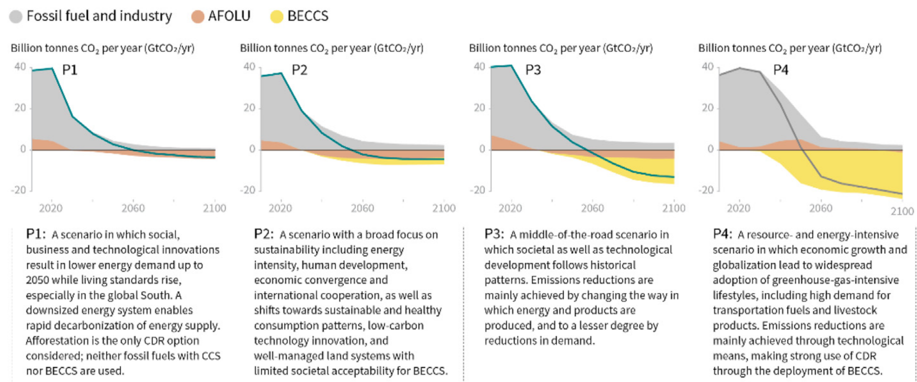


Fig. 1. *Breakdown of contributions to global net CO_2 emissions in four illustrative model pathways [2]. Note: AFOLU stands for Agriculture, Forestry, and Other Land Use; BECCS stands for Bio-Energy with Carbon Capture and Storage; CDR stands for Carbon Dioxide Removal.*

reduction options, but only with a drastic decrease in energy demand. Therefore, energy efficiency and demand reduction are crucial to preserve our flexibility to choose among decarbonisation options with different side effects, reinforcing this message that was already substantiated in the Fifth Assessment Report of the IPCC [7].

According to the International Energy Agency (IEA), buildings and buildings construction sectors are responsible for 36% of global final energy consumption and 40% of total direct and indirect CO_2 emissions [8]. Moreover, the IEA states that the energy demand of these sectors is still growing due to the improved access to energy in developing countries, greater ownership and use of energy-consuming devices, and rapid growth in global buildings floor area, at nearly 3% per year [8].

So, if a drastic decrease in energy demand is needed, we first need to understand why this energy demand is still growing and where in the world each factor is more prominent. The drivers of the energy demand in buildings have been identified as [9,10]:

$$E_{resid}[kWh] = h \cdot \frac{p}{h} \cdot \frac{A}{p} \cdot \frac{E}{A}$$

$$E_{com}[kWh] = GDP \cdot \frac{A}{GDP} \cdot \frac{E}{A}$$

where E_{resid} and E_{com} are the energy use for heating and cooling in residential and commercial buildings, respectively. The activity drivers are h, the number of households, and (p/h), the number of persons living in each household, also called household size for residential buildings, and GDP, the Gross Domestic Product [2005 US$] for the commercial ones. The use intensity drivers are (A/p), the floor area [m^2] per person for residential buildings and (A/GDP), the floor area [m^2] per GDP, in the commercial ones. Finally, the energy intensity drivers are (E/A), the energy [kWh] used for heating or cooling each unit of floor area [m^2], also called specific energy consumption for any building.

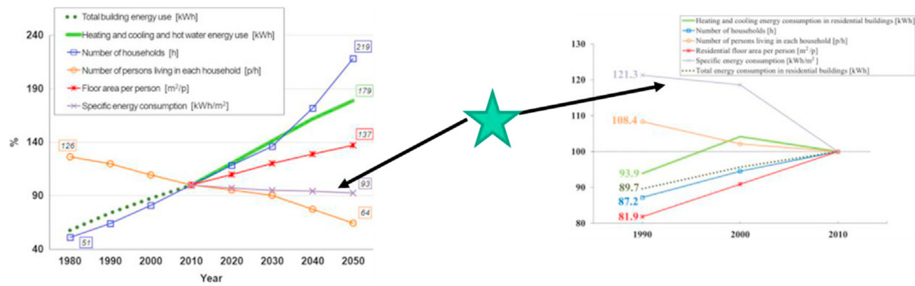
Fig. 2 shows that the specific energy consumption in buildings has decreased in the past and is projected to continue decreasing, although maybe not at the rate desired. Therefore, other drivers and factors need to be considered.

One factor that is to be considered is that the floor area per person is increasing. This may sound odd when today people dwell in small apartments compared to the past where people were living in big farms. But another driver analysed in Fig. 2 shows that the number of persons living in each household is decreasing. This is due to two reasons. The first one is that when a couple is married or goes to live together, they usually acquire a household for them and the children to come, but later on (sometimes no more than about 20 years later) the children move to their own premises, leaving the parents alone with a big household, and with today's life expectancy they may live for another 40 years or more! Another reason for this is divorce. When a couple splits up, they double the living area changing from one household to two, more if there are children involved that live part time with one parent or the other [11]. Divorces may also have an impact to the growth of the number of households (see Fig. 2) and not only the growth of population as one may expect. In general, the tendencies of individualisation and securalisation of societies tend us towards to more people per household, resulting furthermore from the decreased co-habitation of multiple generations, as well as general decreases in fertility in the developed world.

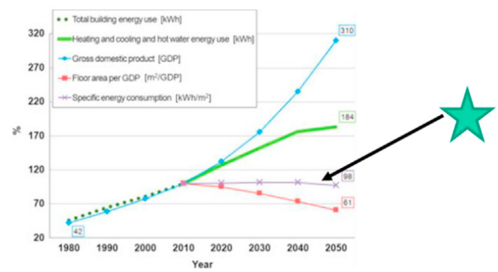
Fig. 2 also shows that the specific energy consumption has been decreasing and is expected to continue to decrease, but the slope of this decrease is much smaller than the increase of other drivers studied. Therefore, again, a dramatic increase in energy demand in buildings maybe witnessed unless policies keep these trends at bay, or compensate for these growing trends in the drivers in other ways.

Recent studies show that, without further climate policies, global final energy demand from buildings could increase from 116 EJ/yr in 2010 to a range of 120–378 EJ/yr in 2100 [12,13]. Literature show a paradigm shift in buildings energy demand. Appliances, lighting and space cooling dominate demand, while the weight of space heating and cooking declines. The importance of developing countries increases and electricity becomes the main energy carrier.

Low energy buildings and zero energy buildings are now a market reality in all climates, in all buildings vintage, and in all areas of the globe, even in low income regions [14]. An example of the retrofit of a massive building in a cold climate achieving Passive House standards is the Vienna Technical University building [15], which reduced drastically the energy demand to levels where the small area of PV installed, the energy recovery from waste heat in the servers and from the lifts is enough to provide all the required energy. There is also increasing evidence that new zero energy buildings do not entail measurably higher costs than conventional new buildings; and deep retrofits pay back well within the lifetime of the building. As the Fifth Assessment Report demonstrated [16], the cost of a unit of energy saved has not been larger with the deepest retrofits than with shallow ones (i.e. those saving only 10–40% heating/cooling energy). In contrast, many other emission reduction "alternatives" such as BECCS, negative emissions technologies (NETs), and solar radiation management (SRM) technologies do not pay back without a carbon price – i.e. energy efficiency



(a)



(b)

Fig. 2. *Trends in the different drivers of energy consumption* [9,10] *in (a) residential buildings (left: worldwide; right: Europe) and (b) commercial buildings (worldwide).*

is a premium choice from an economic perspective, too.

With ample evidence that the global building sector could be turned into a carbon neutral sector at net benefit, with great social benefits such as energy poverty eradication [17,18], if energy savings are counted, complemented by a wide range of co-benefits such as improved equity, social welfare, health, indoor air quality, comfort, etc. – the importance of a zero energy building sector is clear. However, there is a great urgency. Every building that is built or retrofitted to a less ambitious target locks us into a warmer future. Buildings have an average lifespan of 80–100 years [19], so each building today built or retrofitted to a less than zero energy level locks higher emissions in for decades. This lock-in effect was calculated [20] to result in as much as 80% more building thermal energy consumption in 2050 than in 2010, even if today's building energy efficiency policies are fully implemented. Examples of lock-in solutions in the built environment risking the 1.5 °C scenario are partial or incremental retrofits incompatible with a systemic deep retrofit (which means a retrofit achieving more than 80% energy demand reduction) or the replacement of boilers or other HVAC equipment before carrying out systemic building retrofits.

Another aspect is that when considering the costs and benefits of limiting warming to 1.5 °C, a limited number of model studies report wide mitigation costs, but they do not include the benefits of reducing climate change as well as the trade-offs of mitigation.

Considering that carbon budgets are a simplified way to measure the additional emissions that can go into the atmosphere, the IPCC Special Report Global Warming of 1.5 °C [2] gives the carbon budget estimations to 1.5 °C global warming measured in global mean surface temperatures (GMST) with a 50% probability to be 770 remaining $GtCO_2$ vs. the 2200 $GtCO_2$ already spent, which means that we have 17 years left to stop completely CO_2 emissions (if the measured surface air temperature is used, only 8 years are left). This shows the urgency of the actions to be taken.

If these actions are not taken, thinking on the ambitious pathways such as those in Fig. 1, there is also the consideration of intergenerational justice: we are leaving the problem to our children and grandchildren. Intergenerational equity requires that future generations have a right to enjoy a good life undisturbed by the damage our energy systems inflict on the world today, and asks for the promotion of clean energy solutions that implement environmental bonds [21]. However, opting for the pathways that delay the decarbonisation and rely on very aggressive measures in the second half of the century implies a serious ethical decision: we are deferring the challenge of decabonisation to our children and grandchildren who will be faced with these grand challenges of having to pay for massive BECCS or other NETs without enjoying any of the benefits of the fossil fuels that we are burning today to keep our living standards.

There is an urgency that emphasizes the need of avoiding lock-in risks. First, transformational solutions are needed, avoiding incremental measures that compromise a clear change. Second, present mitigation policies may need to be fundamentally rethought. The authors of this editorial consider that demand-side energy transitions, that is energy efficiency first, are the fundamental basis of a climate neutral future if significant environmental and other risks are to be avoided. This is contrary to the present discourse, which often largely equates the energy transition with the supply side and energy production. Finally, intergenerational divide and justice have become the most important issues in this transition.

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